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Nonlinear generation of very high order UV modes in microstructured fibers pumped with femtosecond oscillator

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Abstract: We report generation of high-order spatial modes in the UV range through nonlinear frequency conversion of the femtosecond 800 nm radiation in microstructured fibers. The process is distinct from Supercontinuum generation and is sensitive to fiber tip morphology.

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One of the manifestations of the unusual nonlinear properties of the miscristructured (PCF) fibers is the robust supersontinuum generation from a few centimeters of the fiber with femtosecond oscillator pumping around 800 nm [1]. Even though the fiber can be multimode at wavelengths down to the fundamental, supercontinuum is usually observed exiting the fiber in the fundamental mode. Recent experiments, however, evidenced the existence of other nonlinear effects in PCFs indicating critical role of phase matching between various spatial modes of the fiber [2]. When the PCF is pumped by the 1550 nm femtosecond pulses, distinct visible bands are generated at the output belonging to distinct spatial modes of the fiber.

Here we report that similar nonlinear mechanism exists when PCF is pumped by Ti:Sapphire femtosecond oscillator near 800 nm central wavelength. In this case, however, higher-order modes are generated in the UV range with observed wavelengths up to 310 nm, Fig. 1. Moreover, the effect is observed only when the input tip of the fiber has a non-flat surface, that is freshly cleaved fiber is prepared by melting the tip as described below.

The experiment consists of a femtosecond oscillator delivering 150-fs pulses with average power of up to 1.3 W to the fiber tip. After the attenuator, Faraday isolator and polarization control optics, the light is focused on the tip of the PCF with an aspheric lens. The fiber was a high-air-filling fraction single strand fused silica suspended by a honeycomb web of silica pellicles running along the length of the fiber, which was a few tens of centimeters in our experiments. The diameter of the core was approximately 2.5 microns which makes the fiber highly multimode at 800 nm.

At low pump powers coupled to the freshly cleaved fiber typical supercontinuum is observed at the output. When the input power is increased further a threshold is reached at near 1.1W when the supercontinuum generation suddenly ceases. This was later identified as the melting of the fiber tip by SEM analysis and transverse guiding scans, shown in Fig. 3. Generation of the UV modes is observed after the fiber tip melt at various input power levels but was found to be very sensitive to the input polarization of the fundamental. Two images of the output UV mode profiles are shown in Fig. 2.

These findings strongly suggest that launching the fundamental light into a higher-order spatial mode was critical for the process. The aforementioned threshold corresponds to the melting of the fiber tip after which the tip is no longer flat but rather works as a phase mask for the coupling of the input light. Such a mask decreases the efficiency of the fundamental mode excitation leading to the disappearance of the supercontinuum and increases the efficiency of higher-mode excitation which results in the UV generation through phase matching to even higher-order modes.

References

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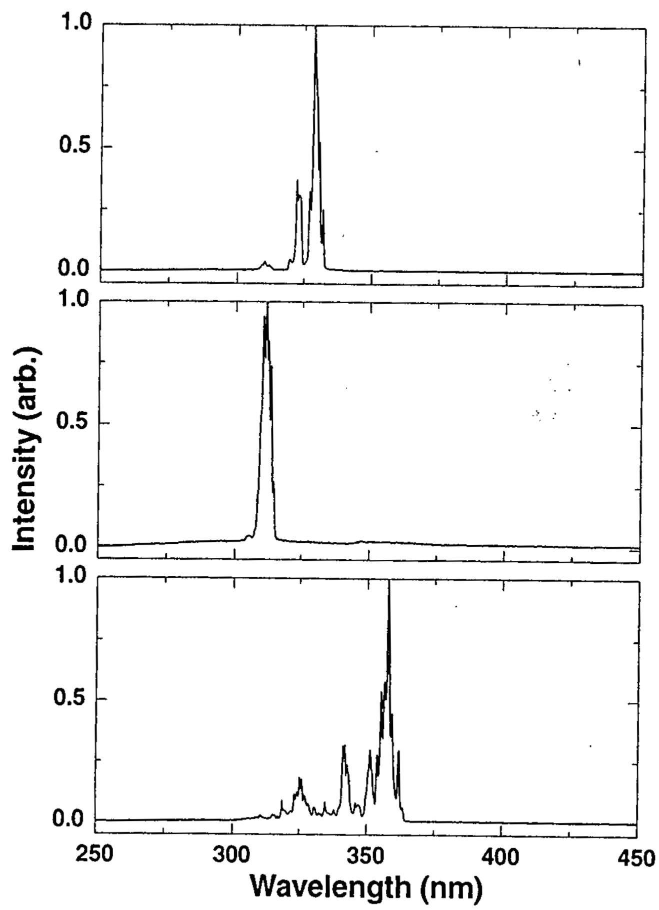

Fig. 1. Sample spectra of the light generated in the PCF around 330 nm in higher-order modes.

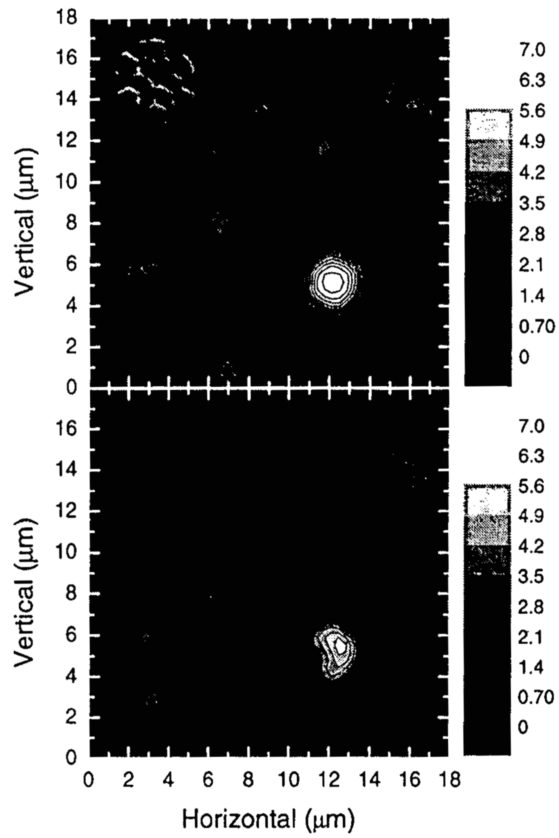

Fig. 2. Transverse guiding scans of the PCF before (top) and after (bottom) the controlled tip melting with the pump laser. Initially the hexagonal shape of the core is well seen, whereas after the melt the change to the core shape is observed. Small guiding regions correspond to the fiber support structure crossings. These scans were taken by scanning the transverse position of the fiber tip relative to the focal spot and measuring the output power at each position.

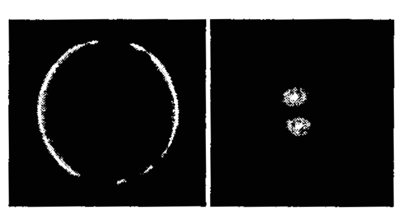

Fig. 3. Far-field spatial mode profiles of the generated UV light. Left: 310 nm, right: 400 nm. On the left image the multilobe ring comprises the mode of interest.

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